Ubiquitous computing is computing power that is integrated in devices and environments in such a way that they offer optimal support to human daily life activities. Instead of going to a single specific device at a fixed location, and explicitly formulating the information or action sought, the environment and devices sense us more or less autonomously and serve us in a proactive, unattended and hardly noticed but effective manner.

For industrial design engineering students, applying ubiquitous technologies offer a great opportunity and challenge for innovating everyday products. To teach the students about ubiquitous technologies and their application in design, we have done an exercise called “Innovate with ubiquitous technologies!” with more than 100 students in our Advanced Design Support-course. The exercise is threefold. The first task for the students is to find information on the Internet about ubiquitous technologies and to share the information found by writing about the collected information in an open content repository (WikID, our industrial design engineering wiki). In the second part of the practical exercise, the students have to create a concept for an incremental innovation of an existing product, and produce an abstract prototype of this concept. They are given a digital computer-aided design model of a product and they have to extend this product by applying a combination of ubiquitous technologies with the goal to improve an aspect such as new functionality, function and price trade off, performance, energy consumption, information richness, and/or user experience. In the third part the students have to make a cost calculation, comparing the product with and without the ubiquitous technologies. For this exercise a design infrastructure, and knowledge sharing sessions have been established including mobile blogs and group sessions and the students have been provided with extended creativity triggering techniques, a knowledge framework for ubiquitous technologies, and design tools. This paper reports on the way these ubiquitous learning applications have been received by the students, and on the results achieved. We present student design cases to illustrate how the exercise has been carried out and to present the students opinions on this ubiquitous learning exercise.

Keywords: Ubiquitous learning exercise and system, Industrial design engineering, Case studies, Student's evaluation, Incremental innovation, Everyday products.

1 INTRODUCTION

Ubiquitous computing is computing power that is integrated in devices and environments in such a way that they offer optimal support to human daily life activities. Instead of going to a single specific device at a fixed location, and explicitly formulating the information or action sought, the environment and devices sense us more or less autonomously and serve us in a proactive, unattended and hardly noticed but effective manner.

For industrial design engineering students, applying ubiquitous technologies offer a great opportunity and challenge for innovating everyday products. To teach the students about ubiquitous technologies and their application in design, we have developed the exercise: “Innovate with ubiquitous technologies!” for our Advanced Design Support (ADS)-course at the faculty of Industrial Design Engineering (IDE) at the Delft University of Technology (TUD). The goal of this practical part of the Advanced Design Support course is on the one hand to deepen the students’ knowledge about ubiquitous technologies to enable them to integrate these technologies in their design results, and on the other hand to upgrade their ability in applying advanced technologies in their design process, such as abstract prototyping, augmented reality, cost analysis and estimation tools, and Web 2.0 technologies like open source content knowledge sharing.

The basic concepts of ubiquitous technologies, Web 2.0, open source content, and abstract prototyping will be shortly described below.

The paradigm of ubiquitous computing is based on the idea of integrating computing power in devices and environments in such a way that they offer optimal support to human daily life activities. Instead of
going to a single specific device at a fixed location and explicitly formulating the information or action sought, the environment and devices that are able to sense more or less autonomously, serve us in a proactive, unattended and hardly noticeable, but effective manner. Gerritsen and Horváth [1] have identified five functional clusters of ubiquitous technologies:

1. Networking technology cluster: Ad hoc networking technologies; Sensor networking technologies; Wireless networking technologies; Ultra wide networking technologies; Internet networking technologies
2. Transmission technology cluster: Embedded transmitters; Ambient transmitters; Portable transmitters; Wearable transmitters;
3. Sensing technology cluster: Sensor materials; Embedded sensors; Ambient sensors; Wearable sensors;
4. Exploration technology cluster: Data/information miners; Knowledge repositories seekers; Content search engines; Object retrieval engines;
5. Conversion technology cluster: Visual sensation converters; Haptic and tactile sensation converters; Thermal sensation converters; Audio sensation converters; Behaviour sensation converters; Interaction sensation converters.

The first implementation of the World Wide Web in 1990 included just one Web site and one browser. Right from the beginning, multi - point information sharing was the main issue of the Web [2]. Web 1.0 allowed users to passively view information availed for them. Emerged in 2004, Web 2.0 enables users to share and generate content. Examples of Web 2.0 include web - based communities, webhosted services, web applications, social - networking sites, video - sharing sites, wikis, and blogs. The term Web 3.0 has emerged as well but the definitions of Web 3.0 are not quite consolidated. Andrew Keen, author of The Cult of the Amateur has an interesting opinion about Web 3.0, being the return of experts and authorities to the Web [3].

An open content repository has a formal knowledge structure and allows designers to share information and knowledge across organizational boundaries. Such a repository can be used to collectively construct knowledge about ubiquitous technologies in a social way. An example of an open content repository is WikID [4], which is a Web 2.0 application especially for industrial design engineering. WikID can be accessed at the website www.wikid.eu, and includes the complete Delft Design Guide [5], and collections of articles on design tools [6], ubiquitous technologies and abstract prototypes [7].

2 THE “INNOVATE WITH UBIQUITOUS TECHNOLOGIES!” EXERCISE

The objectives of the exercise “Innovate with ubiquitous technologies!” are threefold. Firstly it is intended to enable the students to get hands on experience with Web 2.0 and with aggregating information on ubiquitous technologies. Secondly, it will provide the students the opportunity to practice abstract prototyping and apply cost estimation in association with an innovation exercise. Finally, they will be taught how to report knowledge and information articles on wikis, or other knowledge portals of industrial design engineering. By the end of the course the students will be acquainted with a large number of ubiquitous technologies. They will also share their knowledge and experiences with other fellow students by collectively writing articles about the technologies and exchange their experiences by presenting their exercise results to each other. The students will work in a team of 2 or 3 students. The assignment has three main tasks: (1) web search and information gathering about selected ubiquitous technologies, (2) product innovation with ubiquitous technology combinations and abstract prototyping of the created product ideas, and (3) cost estimation of the product idea with and without using ubiquitous technologies.

2.1 Web searching

In the first part of the exercise, the students will search information about one networking technology or transmission technology assigned to them and at least one other ubiquitous technology from the three functional clusters (sensing, exploration and conversion) listed in section 1. The students can divide this task of searching for ubiquitous technologies and reporting among the members of the group. Each member of the group should contribute with approximately 10 work hours in order to complete this part of the assignment. Searching on Internet will be done by using meta–search,
collaborative search, visual search, or by a search engine other than Google, such as DuckDuckGo\(^1\). The students have to consider the following questions when describing the ubiquitous technologies: What the technology can do? What are the typical application fields, domains and products using this technology? What is the working principle? What are the information processes? What are the inputs of the technology? What are the outputs? What are the performance characteristics? Once they have collected the information, they have to create an article on the WikID website and include links to the relevant websites that have been used as information sources. In their WikID article (or section) they should write a short review and explanation in a way that is helpful for designers. They have to pay attention to avoid any copyright violation or plagiarism. The article should end with a “further reading” section including references to e.g. sites or books about the article’s topic.

2.2 Abstract prototyping

In the second part of the practical exercise, the students have to create a product idea for an incremental innovation of an existing product, and produce an abstract prototype of this product idea. A CAD model of a product will be available to them on blackboard or they may alternatively choose to use a product concept from a project they are working on. Their task is to extend this product by applying a combination of ubiquitous technologies with the goal to improve a selected aspect such as new functionality, function and price trade off, performance, energy consumption, information richness, and/or user experience. For this part of the assignment 20 hours/person study time should be allocated and used. The deliverables are a blog on blackboard as specified in the task description and an abstract prototype (i.e. narrated movie) illustrating the innovative idea and its benefits. As a first step, they will organize a brainstorm session with the group and use the assigned product, the assigned networking or transmission technology, and one or more tentatively chosen exploration, sensing and/or conversion technology as input for their discussions. The objective of this brainstorm session is to generate product ideas and use scenarios, in which they consider the following features of the ubiquitous products:

F1: omnipresence in terms of functional affordances in space
F2: permanent readiness for operation in time
F3: small, functional, low energy consumption
F4: problem solving is based on a cooperating cluster of entities
F5: entities may be embedded in host artefacts
F6: smart reasoning and adaptive information processing based on sensing, mining and communication
F7: artefacts/services interact with and impact the user in cognitive domain
F8: history, situation, user and context awareness is remarkable

![Radar chart to illustrate the ubiquity level of product ideas.](http://duckduckgo.com/)
Their three best ideas have to be evaluated in Excel, rated on a scale of 0 - 3 for each ubiquitous feature, and these rating results can be presented in a “radar” chart (see figure 1 for an example). Then the students can select the idea which has the highest potential in their view.

Now the students can create an abstract prototype in the form of a 4 - 6 minutes movie about their selected innovative idea [8]. The audience consists of product developers like themselves, who know nothing about the product but can recognize potential of it and understand technical issues. First, they will create a storyline in a form of a narration, which tells in an attractive and clear manner, what the product can do in a ubiquitous environment, and what the innovative aspects of their concept are. This narration will be used as a basis of their abstract prototype and they will complete it with an enactment (i.e. a rich visual presentation). The students have to use augmented reality as a means to mimic the use scenario of their ubiquitous product idea and record the interaction with their new design [9]. Next to the augmented reality tool we suggest to use tools like paper prototyping, markers, scanners, computer graphics and moviemaker software. The movie will be uploaded to YouTube with a link to this movie on their WikID page as well as on their blog on blackboard. The student teams must report about their process of product idea generation and prototyping on a blog. The blog must cover at least the following topics: 1) which aspects of the product are to be improved by the innovation, 2) three concept descriptions coming from the brainstorm session, 3) a radar chart of the ubiquitous feature profiles and the choice that they made, 4) the rough narration that is the basis of their abstract prototype, 5) produced illustrative materials, and 6) their own evaluation of the final abstract prototype. The blog must be concise but adequately cover the mentioned topics.

2.3 Cost analysis and estimation

The objective of this part of the assignment is to enable the students to learn and practice the art of cost analysis and estimation. They will be able to practice e.g., how changes on product models translate directly to product cost in real-time when estimating cost by using a selected cost estimation software [10]. They will consider their group to be a team of designers in a firm who are tasked to convince the management team that the innovated product idea meets cost criteria. The students will reflect back on the aspects they have taken into consideration at making decision of what type of ubiquitous technologies can be integrated in their product. Validate their ideas by making an estimation of the expected benefits. Estimate the production cost of the product with and without the ubiquitous technologies, see figure 2.

![Figure 2 Cost and price comparison (illustration from a cost analysis report).](image_url)

They have to conduct a comprehensive cost analysis for the product and explore the market to determine its target cost (and of its components) and use them in making cost estimates. They have to make effort to minimize cost, of course, without sacrificing other aspects of their design, such as manufacturability, easiness to assemble parts, reliability, and functionality. One needs to know the product in details, i.e. its components, the materials the components are made of, the material costs, the machining costs, the overhead costs, the labour cost, etc. In order to be able to make reliable cost estimates, the students are required to use the provided CAD model as the basis for their analysis and estimates. They have to search the literature and the internet for these costs or use databases, such as the CES database. In the event they cannot obtain information, assume a reasonable value and
use it for estimating cost (method is more important than the final result). The students have to write
down a brief report describing how they arrived at their estimate. The proposed structure of the report
is as follows: Title Page; 1. Introduction (background overview and problem definition); 2. Analysis; 3.
Cost estimation process and methodology; 4. Evaluation and Conclusion; Appendices: CAD models
printouts, BOM documents, cost estimate summaries (Snapshots e.g. showing cost allocation, ABC
analysis and cost safety). For this part of the assignment, 10 hours of study time is allotted.

2.4 Compulsory presentation

Each group will make a 10 minutes presentation about their product idea including their abstract
prototype, followed by a 5 minutes discussion with the audience. The presentations are scheduled in
five parallel sessions where approximately 8 groups will share their knowledge about ubiquitous
technologies and present their product ideas.

3 METHOD

For this exercise a design infrastructure, and knowledge sharing sessions have been established
including mobile blogs and group sessions. The students have been provided with extended creativity
triggering techniques, a knowledge framework for ubiquitous technologies, and design tools. See [11],
[12], [13] and [14] for this and the related learning systems.

Although the exercise has not been set up as a research experiment, it includes a number of new
elements and the results of the exercise provide us with a large amount of interesting data to evaluate
the new elements and the aimed objectives. Furthermore, the evaluations of the exercise by the
students will be studied. The more they appreciate the exercise, the more they will be motivated, and
this has in turn a positive influence on the learning results [11], [15].

We have been observing the students, have read their WikID articles on ubiquitous technologies and
their design blogs and we have watched their abstract prototypes and their presentations. This paper
reports on the way these ubiquitous learning applications have been received by the students, and on
the results achieved in the exercises and in the knowledge sharing actions. We present student design
cases to illustrate how the exercise has been carried out.

4 EXERCISE RESULTS

Articles on ubiquitous technologies. The articles on ubiquitous technologies that have been written by
the students have been stored as a collection in WikID², making up a source to find and select
technologies to incorporate in their product ideas: more than 100 ubiquitous technologies from ZigBee,
through E-skin sensors, haptic devices and smart dust to electro-active polymers. All these articles
include references and further-reading links and most important: the articles have been written for an
audience of design engineers. These articles in WikID have been positioned under the framework
headings for ubiquitous technologies as presented in section 1.

Brainstorm session to create three product ideas. Having some basic knowledge on the ubiquitous
technologies, the students were prepared to enter a brainstorm session for creating three product
ideas of everyday products enhanced with ubiquitous technologies. The students received CAD
models of every-day products, such as lamps, office chairs, air heaters, bicycle pumps, screw drivers,
hair driers, etc. The resulting product ideas show that the design students were able to incorporate the
newly found technologies and come up with a broad variation of new product ideas. Because of the
limited amount of time available for the students, and the preconditions of the specified product and
network technology, the product ideas have limited reality value. Nevertheless they show the ubiquity
opportunities. Here is an example of three product ideas created by one team who have to combine a
portable transmitter, a sensing device and an air heater in a ubiquitous environment:

1. A sensor embedded in the user’s clothes detects the body and the outside temperature.
Based on these data the heater will analyse the optimal environmental temperature and sends
this information via Bluetooth to the air heater. The air heater in turns adjusts its intensity to
accommodate this optimum temperature.

² http://www.wikid.eu/index.php/Category:Ubiquitous_Technologies
2. A bracelet senses the actual temperature and the light temperature surrounding the user. The bracelet sends information via Bluetooth to the air heater which in turn adjusts its intensity level to these temperatures. This will create more stimuli for different senses of the users.

3. The air heater is fitted with an ambient light sensor to determine the light temperature of the room. Combined with the actual temperature this can be used to set a mood in the room. The air heater is also fitted with a Bluetooth transmitter which is able to control the user’s stereo set or iTunes. It selects a playlist of music that fits the current atmosphere in the room; for instance active music on a bright warm moment of the day and more slow and calm music during sunset and night. See figure 3.

![Figure 3](image)

**Figure 3 I-air-heater-which-can-turn-on-your-music-player.**

These product ideas have been evaluated by considering the seven features of ubiquitous products listed in section 2, which resulted in the radar chart that is depicted in figure 1.

**Abstract prototype.** The abstract prototypes illustrate the creativity of the students and moreover the learning results of the exercise. 41 Teams have created an abstract prototype including augmented reality and presenting a newly conceptualized product idea with embedded ubiquitous technologies. Most abstract prototypes clearly demonstrate the positive and cheerful attitude of the students towards this project, carefully produced and often funny, following the given guidelines and presenting interesting product ideas and use scenarios. The abstract prototypes can be found in WikID³.

Example 1. The assignment was to enhance a cordless drilling machine with internet networking and another ubiquitous technology. The new product idea supports amateur users of a drilling machine with up to date knowledge available from an online community, and guides them in their use of the machine. It provides feedback to the user and makes internal adjustments after context-based data acquiring and throughput, figure 4. In the new ubiquitous drilling machine an image sensor is embedded to register the kind of bit attached to its head. Also, the kind of screw is registered when the screw is placed on the bit. This information is sent online, and is compared with the data in a knowledge repository. The drill can connect to a Wi-Fi connection using auto-configuration. If the combination of the bit and the screw is not optimal, a message will be sent back to the user which is displayed directly on the display of the screwdriver. An embedded pressure sensor registers the force applied to the bit. The device is capable of making adjustments in angular velocities to optimize power use for instance.

![Figure 4](image)

**Figure 4 Screenshots abstract prototype of a ubiquitous screw driver.**

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Example 2. Use scenario for a product idea for a food mixer: The user would like to bake a cake. He selects a recipe in the display of the mixer. Then the mixer asks the refrigerator and the food storage if all the ingredients are available. The refrigerator informs that there are no lemons, and asks the user if he would like to obtain recipes with only ingredients that he has. He chooses from the filtered recipes and sees the ingredients that he needs in the display. While the user collects all the ingredients, the mixer alerts about to change the tools. The system detects the type of tools by a low-tech mechanical-contact sensor. Once the user has changed the tools, and put all the ingredients in the mixer, the mixing start and sends a request to the oven to preheat at 220 degrees Celsius. The mixer will show the next steps of the recipe.

Example 3. The ubiquitous drill, the wall eye, is equipped with wireless networking and embedded sensors. With a sonar sensor, the thickness and density of the wall can be determined. This sonar sensor can also create an echo-image to determine whether there are any gas-water pipes or electric wires present in the area the user is about to drill or screw. A beamer is present to project a working area on the wall. This beamer is fitted with motion sensors which can detect movements of the user so the projected image can be used as a touchscreen. The screwdriver will be connected to the beamer where advice can be given how to screw/drill without damaging any pipes or wires and without causing any injuries. The screwdriver can be used as a remote control for the beamer.

5 EVALUATIONS

In the blogs and in the cost analysis reports students have written about their experiences in the exercise. The evaluations in these files mainly discuss the abstract prototypes and the cost analysis software because these evaluations were explicitly asked for. Nevertheless, numerous evaluative comments have been found in the documents about several aspects of the exercise and the system. The selected and shortened comments and citations from student works below express the tone in the evaluations.

On the effect of the WikID articles.-The first step was to identify and search about the technology assigned to the group. In this case, in addition to the wireless technologies, one more technology should be selected by the team. Afterwards, with a wider knowledge of the topic, a second brainstorming session was conducted to find out which aspects of the product could be improved and by which means.
About the ubiquity of the product idea. -This device is always ready and omnipresent without bothering the user with its complexity and structure. Hence the product idea reached a ubiquity level.-

-Combining a screwdriver with a transmitting technology can not be done without adding another ubiquitous technology (sensing, networking, conversing, exploring) as well. Without these, there would be nothing to transmit or there would be no receiver. Therefore we added a sensing technology to all concepts as well, to generate the data to transmit. Next, we determined that if there was interaction with another product, it would already have the needed technology to receive and process the transmitted data.-

-We have made WikID-articles about face recognition and smart lighting. Since smart lighting is a communication technology, we were not sure whether we could use this in our concepts, because it has little to do with the actual functionality of the lamp, which is creating an artificially lit environment. We thought about how to make an office lamp smart. This brought us to the questions: How do we perceive light from a lamp? What kind of light do we want for certain activities? What could we do with a new office lamp with embedded intelligence? This resulted in three product ideas: (i) an office lamp that learns the user's preferences; (ii) an office lamp that adapts the light intensity to the environment; and (iii) an office lamp with the power to sense motion and project feedback.-

About the reality level of the product idea. -The product idea, as it is now, is mainly an extension that is mounted on the front of the drill. In our vision, the ideal situation would be to enable customers to mount this tool on the front of the drill they already own, which means the product would have to be compatible with just about every drill on the market. This idea is quite realistic and realizable; the only big problem would be the electronics. The extension needs to be connected to the electronics of the drill and preferably it would receive power from the drill's battery-

-It is questionable that the extra features of the new cake decorator will offset the higher price. The difference between a one euro normal cake decorator and a 31 euro cake decorator with ubiquitous technologies is very big. We presume that this is too much. In the current concept design a lot of sensors are integrated in the oven. It would be better if the cake decorator can work on itself in combination with a smart phone. It is quite an operation to get all ovens equipped with a system that can communicate with a smart phone. However, maybe in the near future this will be the case for most ovens. Than our concept design is suddenly much more feasible. -

-We think the product concept as presented does not have much real-world value, though it might still come to exist in the future when the components used become sufficiently cheaper.-

About the exercise. -There are many things that are thought to be impossible to improve, most of the cases these thoughts are caused by a limited awareness of the current technology possibilities. Ubiquitous technologies are amongst these new technologies that can improve many products and systems. The lack of knowledge is one of the big problems which designers have in new projects. Often they are reticent to try something new or they are even ignorant about solutions that can be helpful or determinant. An industrial designer should have the knowledge about ubiquitous technology systems since they might play a very important role in the future of industrial design. Doing this assignment we have discovered the different components and how they interact and communicate to each other to create a ubiquitous system. In fact it can be said that after doing this assignment we have a better understanding of the meaning of ubiquitous technology. However the most important point about this assignment is that we have gained new ways of solving and facing future design problems. From now on ubiquitous technology might be the necessary solution for many problems we can find from now onwards.-

-We consider the hair dryer as a difficult subject for this project and think it is ill-fit to be combined with ubiquitous technologies, similarly for a comb or a can of hairspray.-

About the abstract prototyping means. -The augmented reality tool used is usable for human-product interaction. On screen can be seen how a person interacts with the heater when manually adjusting the temperature. But this technique has its shortcomings. No haptic feedback is offered. The user has to see on screen when the product is touched or not. A shortcoming is that no real heat is experienced, while temperature changes in a prototype for an air heating system would be desirable. Altogether the abstract prototype is able to present the ubiquitous air heating system in a proper way.

-By making the abstract prototype we experienced that we gained a better understanding of all aspects of the product. In an early stage we had to think about certain product characteristics and inner workings, which we normally only would think of in a later phase of the concept development.
We also discovered that it is very funny and weird to narrate a story with our own voice and found it hard to make it sound convincing. Overall we are quite satisfied with our abstract prototype movie.

-The use of augmented reality to visualize the concept was not useful for this particular product idea but it convinced us that it would be very useful for other projects. For the current project we needed to simulate moving components which was not possible with the software, resulting in a video where the extension does not slide in and out during the drilling simulation with the tool.

-We think this abstract prototype shows the high potential of ubiquitous technology and we think ubiquitous technologies can make life easier in the future. In making the movie we tried to use as many dynamic elements as possible. Especially in making the augmented reality scenes this was quite a challenge because the marker of course had to stay in the camera view. We think quite some improvements still need to be made to the AR software to make it a more valuable tool. However the technique is promising and it was very interesting to work with it. We enjoyed it very much.

-We look forward to see the AP of the other groups and see what choices they made and software they used. We did like the assignment, but wished we had more experience with the software that was needed to complete this exercise, to give it a more professional look.

-Explaining a concept with an abstract prototype was a new experience for us. It's a good way of presenting a concept in an early stage. It saves a lot of prototyping costs and time.

About the cost estimation tool -The advantage of the cost estimation tool is the structured way of assigning costs to every part of a product, which makes the estimation more reliable. Another advantage is the use of the CAD model as input for the volume of the part, and that it is updated automatically. The shortcoming of the software is that many aspects have to be filled in by hand, and should be found outside the program, where you expect that more information about different cost aspects is available within the program. Only cost information of materials is delivered, where more unknown features like tool costs, production costs, transport and overhead are left out. Particularly these are hard to find, yet very valuable if you want to make a quick estimation. This way it is hardly advantageous over the use of an excel sheet. The cost estimation software is probably more suited for more complex products and large design companies where different departments need to work on the same product. It is not suited for a quick estimation in the begin phase of the design process, but more for embodiment design and the optimisation at the end of the process.

-The biggest issue we could not really resolve was the fact that we did not know half of the prices we needed. We found it very hard to find concrete prices for operating machines or how much labour it would take to operate the machine.

-Throughout our studies, each of the team members have developed their own Excel spread sheets we use as templates, making us question the purpose of the available cost estimation software. As we advanced with the project, having the tasks frequently switch hands we quickly realized likely its biggest advantage, standardization. Having a uniform costs analysis suite used in an industry allows for a smoother communication of costs, trade-offs and decisions between the various parties involved (designers, marketers, manufacturers). Using computer aided design tools such as CAD requires the user to fully trust its accuracy, which in turn requires a thorough understanding of the processes involved. The cost estimation software is not as transparent as we would desire, often leaving us in the dark about what is happening on the screen.

6 DISCUSSION AND CONCLUSIONS

An important achievement of the exercise is that the students realize that they need the knowledge about ubiquitous technologies and advanced design techniques to be able to consider the application of these technologies in their product development projects. They recognize the high potential of ubiquitous technologies and expect ubiquitous systems to play an important role in the future of industrial design. The students’ evaluations show that they acknowledged the learning results in many of the aimed learning objectives. They reported that finding and sharing information about ubiquitous
technologies broadened their knowledge in this area, which helped them to come up with ubiquitous product ideas. It must be said however that they were also provided with lectures and a reader.

The reported experiences with the creation of the abstract prototypes indicate that the students see various reasons for making abstract prototypes and using AR software more often in their design projects. They enjoyed it and they found it very interesting. But even when the augmented reality AP was not useful for their specific product idea, students show their insight in the usefulness of AR for other projects. Although there were also a few critical notes indicating that the software needs some (unspecified) improvements, the techniques have been assessed as promising and very interesting to work with. The ability to create a model without actually building a physical one was appreciated, and also the flexibility for adjusting the product idea. Some students encountered problems using one or more software tools because they had not used these kind of tools ever before. Although they were able to overcome these problems it took them more time to do the exercise. This struggling with the tools made the students eager to see the results of their fellow students. They were looking forward to the knowledge sharing sessions in which the students had to present their results to each other.

The exercise “Innovate with ubiquitous technologies!” has been done by more than 100 design students at Delft University of Technology. The observed results of this exercise lead to the conclusion that the students learned about numerous ubiquitous technologies. They understand that products can be more or less ubiquity rather than either or not. They have gained experience with open content repositories and collaborative search on the internet, and they have gained hands-on experience with the application of augmented reality and creating abstract prototypes. The evaluation statements of the students show some insights in which situations are appropriate for applying these technologies. And finally they have gained some insights in the cost and price consequences of ubiquitous product ideas and some hands on experience in applying a cost estimation tool.

The knowledge sharing issues enriched the learning experiences in the limited available time for the exercise. While the students gathered ubiquitous technologies and abstract prototypes in WikID, they simultaneously gained practical experience in relevant technologies and created a knowledge source for the whole group. The presentations at the end of the exercise again broadened the students’ knowledge on the application options of ubiquitous technologies and advanced design techniques by watching abstract prototypes and presentations tailored for design students.

ACKNOWLEDGEMENT

We would like to acknowledge the students of the Advanced Design Support Course 2011 for creating valuable material for this evaluation. The students whose results have been used in this paper are: K. de Waard, F. van Midwoud, L.J. Bolier, J.E.P. Duwel, B.S. Groeneveld, J. Gimenez C., P. Noguera, R. Blokdijk, P.-B. de Visser, J. de Vreede, C. Magert, D. Manning, and J. Noriega. They are also the creators of the graphical illustrations in this paper.

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